A Multidimensional Theory of Geographic Features and Relations.

Objectives

The objectives of this project are to develop a multidimensional theory of geographic features and the relations among them. Currently, features are based on either raster or vector geometric models. Theoretically, the geometry is only another attribute of a geographic feature which also includes attributes of type or kind, time, etc. Representing the feature as a composite of space (geometry), theme (characteristics), and time (date) captures all possible dimensions of the feature and allows for dynamic modeling and establishment of relations among features. This project will implement a multidimensional theory and develop methods for representing relations, such as distance, direction, containment, etc., among geographic features.

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Hypotheses: 1) Human cognition of geography is multidimensional and a multidimensional representation will be easier for humans to use in modeling and analysis processes. 2) Results of modeling and analysis based on a multidimensional theory will be superior to traditional results based on geometric models.

FY 2000 Deliverables

- Multidimensional representational theory.
- Database of elevation, digital images, soils, land cover, and hydrology for test sites.
- Representational methods for relations among features.
- Analysis operators and model for using multidimensional theory of geographic features.
- Paper presentation and publication.

FY '00 Funding

NMD-SIR

Salaries -- PI, 0.2 FTE; GS-11 Technician, 1-FTE; GS-11 Computer Specialist, 1/2 FTE

Equipment/Software	$10,000
Mapping Contracts	10,000
Travel	5,000
Training	2,000
Books, misc.	1,000

Equipment/Software	$10,000	High-end Windows NT workstations, math and process modeling software, license ERDAS Imagine Developer's toolkit

Approach

The approach to this project is to use the fundamental basis of geographic phenomena (Table 1) to arrive at a representation intuitive to humans yet efficient in computer implementation (Berry, 1964; Sinton, 1978; Usery, 1996). The project relies on basic concepts of data modeling developed in computer science and geographic information theory. A data modeling approach recognizes the move from the real world to a selection of geographic phenomena to be represented, *i.e.*, the data reality defined by Guptill *et al.* (1990)**,** to a data model, and finally a data structure (Figure 1) (Usery, 1996). The ultimate end is the development of a features knowledgebase for a specific application, in this case watershed modelling.

Table 1

Attributes and Relationships of Fundamental Geographic Dimensions

Feature	Space	Theme	Time
Attributes	ϕ,λ,Z point, line, area, volume, pixel, voxel, ...	color, size, shape, pH, ...	duration date, period, ...
Relationships	topology, direction, distance, ...	is_a, kind_of, part_of, topology, ...	is_a, was_a, will_be, topology, ...

Workplan

The workplan for this research consists of two distinct phases, theoretical development of representation methods and implementation for a specific application. The theoretical development will expand the concepts presented in Figure 1 to develop specific methods for representing watershed features, *e.g.,* basins, subbasins, streams, sampling stations, flow planes, etc**.,** with the attributes and relationships of Table 1. The implementation will consist of developing a watershed modelling application from the theoretical structures. For example, flow of water, sediment accumulation, and pollution transport through the watershed will be modelled as a function of space and time with dynamic visualization. The modelled results will be compared with actual measurements of flow, sediment, and water quality parameters.

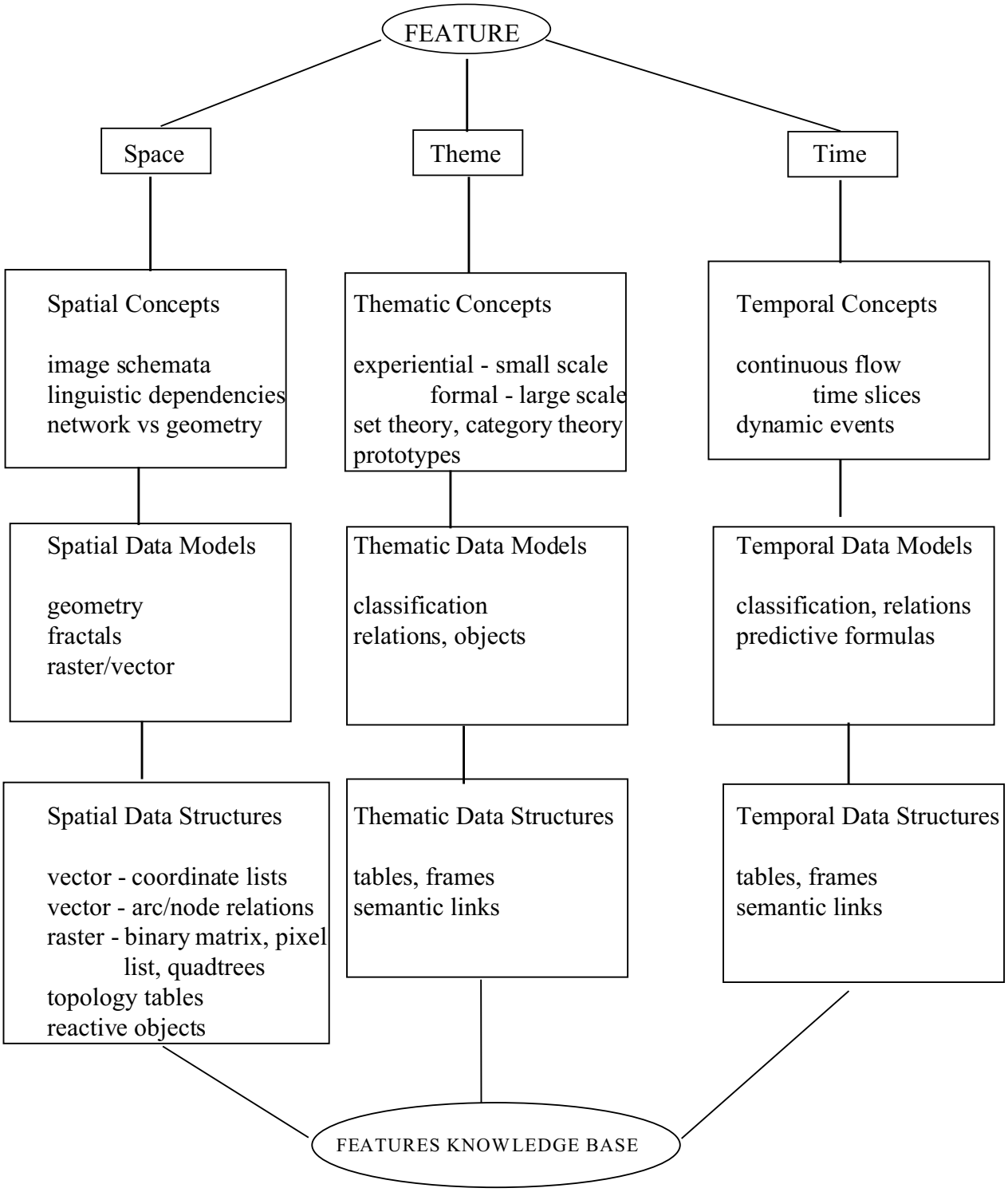

Figure 1: Data modeling concept of implementing a multidimensional geographic theory (Usery, 1996).

Developing Representation Methods

The method of representation for specific geographic phenomena depends on the source information and the application. For watershed features, terrain data, land cover, soils, and precipitation comprise the basic data sources. Representing subwatersheds requires delineation of the area of the watershed from the terrain database, then attaching spatial, thematic, and temporal attributes to the feature identifier for the subwatershed. Relationships to other features, *e.g.*, other subwatersheds and the entire watershed itself requires structuring containment (part_of, composed_of) and hierarchical relations (is_a, will_be) as well as topology for spatial, thematic, and temporal dimensions. While all relations cannot be defined, a mechanism to compute or determine the exact relationship must be developed.

The theoretical structure and the implementation will be developed from feature-based and object-oriented concepts, respectively. Features exist in the real world and are represented as objects in a computer program or database.

Programing Support Needed

This is a theoretical project and requires programing support to demonstrate feasibility. The theory uses the feature (geographic entity with multiple object representations) as the basic organization of all data. As the theory is developed and elaborated, appropriate data structures which interface with object-oriented databases must be developed. The following tasks represent the work:

1) Develop basic object-oriented data model/structure to support multiple object representations (vector, raster, multiple resolutions, different representations) of a single geographic entity.

2) Interface basic structure to current generation object-oriented databases.

3) Develop operators on basic structure to demonstrate utility.

Technical Skills Requirement

GIS skills to construct terrain databases including population, landcover, hydrography, DLG, DOQ, DRG, etc from global to high resolution local extents. Work in Arc/Info and Imagine. Skills to work with development team to process data and run analysis, program testing as software is developed.

Database management system software (MS Access) will be used to develop a project bibliographic database to document and archive status of current theory. Approaches and methods published to date toward geographic information theory development will be classified.

Training for Technicians Classes in Arc/Info and ***Imagine (Nov 29 - Dec 3, 1999 at MCMC***) as necessary.

Training in Imagine is already scheduled.

Calendar GIS database construction with existing datasets can begin immediately. These databases will be constructed from existing sources and should begin as soon as personnel can be assigned. Programming of the basic structures as objects can also begin immediately and advance as the theory progresses.